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ABSTRACT

This paper describes and comments on a seven year old's experiences with turtle graphics in order to explore some important issues with regard to using computers in education and to probe into the question of what programming ideas and projects will engage young children. The case study which is described took place at the Artificial Intelligence LOGO Lab at the Massachusetts Institute of Technology where the child, a second grader, spent several hours on a consecutive Saturday and Sunday, talking in LOGO to a display turtle and a PDP-11/45 computer, and engaging in debugging sessions. Nine references are listed. (Author/LLS)

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A Case Study of a Young Child Doing Turtle Graphics in LOGO

by

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and
Seymour Papert**

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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A B S T R A C T

This paper explores some important issues with regard to using computers in education. It probes into the question of what programming ideas and projects will engage young children. In particular, a seven year old child's involvement in turtle graphics is presented as a case study.

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**Comments by Dr. Papert

The research described in this paper was conducted at Massachusetts Institute of Technology in the Artificial Intelligence Laboratory's LOGO Group in 1975, under the support of the National Institute of Education Grant No. NIE-G-74-0012, and of the National Science Foundation Grant No. EC-40708X.

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A case study of a young child doing turtle graphics in LOGO*

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ABSTRACT

This paper explores some important issues with regard to using computers in education. It probes into the question of what programming ideas and projects will engage young children. In particular, a seven year old child's involvement in turtle graphics is presented as a case study.

This paper describes and comments on the experience of a young child in the MIT AI-LOGO Lab where she was involved in talking in LOGO to a display turtle and a PDP-11/45 computer. The child, a second grader, spent several hours on a consecutive Saturday and Sunday engaged in interesting debugging sessions. She worked long and hard. Why she could do so and why the experience was so interesting is partially explained by looking at her past experiences. In mid-January, the year before, when she was a first grader, she and I started working together learning about turtles and their world and thus explored turtle graphics. She visited twice a week for a month, staying from ½ to ¾ of an hour. We continued to meet, but less regularly, until the end of April. During that time she learned to talk to the display turtle. She learned the LOGO turtle commands like CLEARSCREEN (CS), FORWARD (FD), RIGHT (RT), LEFT (LT), PENDOWN (PD), PENUP (PU); and she learned to use them to make up her own commands for the turtle.

My goal for her first year had been for her to understand procedures both by using them and constructing them. She was given the following kind of experience. She made the turtle draw something by a series of direct commands. She would then think of a name for the picture (or piece of picture) and teach that word to the computer. To help her in this construction I wrote down the commands as she debugged them. When she "taught" the procedure to the computer she would either read the commands as I had written them or I would read them to her. Then she would try out or "run" the procedure and see if there were any bugs.

The kinds of debugging situations Est encountered varied but I was always ready to intervene in case the situation became unresolvable for her. I presented Est with the same kind of materials and projects as I developed for older children. What I expected to see with a young child was a clearer indication of where bugs in the material and ideas lay, e.g., what ideas are hard to grasp and what ideas can be understood if presented in a crisper manner or imbedded in better situations. From the sessions with Lin, another first grader I had worked with quite extensively, I developed techniques and aids which have helped older children get into turtle work, and subprocedurization, debugging, anthropomorphizing.

Let me back off a bit here and explain what preparations I had made. To aid kids in defining procedures and to exploit the idea of teaching things to the computer I provided a procedure called TEACH. This command was used instead of LOGO's TO for defining procedures. TEACH requested a name for the procedure to be defined and then asked for each instruction of the procedure by saying "STEP 10:" etc. until the child typed "END". Thus line numbers were assigned to each instruction starting at 10 in increments of 10. I also prepared procedures for making squares, circles and pieces of circle. They require inputs, which allow their size to be varied. The child also had the choice of using either RSQUARE or LSQUARE, RCIRCLE or LCIRCLE, RARC or LARC. For example, could be drawn by RSQUARE or

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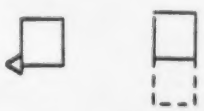
LSQUARE; only the turtle's starting and stopping states indicate which procedure should be used. All of these procedures were treated as primitive commands. Nonetheless, most children will teach the turtle to make a square or circle of fixed size by using FORWARD and RIGHT, thereby understanding the turtle's behavior in the process.

The turtle became more than a drawing device. It was a creature with certain behaviors which are interesting to study and might help us understand ourselves. The turtle lives on a display screen. Its initial state is in the middle of the screen with its nose pointing north or at 0 degrees. We can change its state by telling it to move FORWARD some number of units or turn RIGHT some number of degrees. We have marked the screen with 4 differently colored labels, NORTH, EAST, SOUTH and WEST. So we begin to build up a description of the turtle which is outside of the words provided by the LOGO language. Some of these we use to form a meta-language while others we turn into LOGO commands.

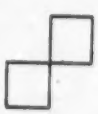
The previous remarks are meant to be background to the core of this paper, which is a picture of Est's two day interaction in the turtle-LOGO world after a break of almost six months. When Est arrived there was an initial bit of awkwardness. Her father was with her and wanted to see what kinds of things she would be doing. The work area was drastically changed. And Est wore a patch on her left eye. Her work from six months ago was in her workspace. I suggested she show her father her flower, a rather spectacular piece of opportunism. She exclaimed, "Oh yes you say CB seven times for this." She did it, her father satisfied at having seen something and reassured that she could see, left. We then abandoned last year's work and proceeded to reinvestigate the turtle's behavior. She remembered turtle commands in their abbreviated form like CS, FD, RT, LT, BK and also TEACH. She had difficulty remembering how to execute commands. That is she forgot to press the CR button and she also forgot to space between words. Last year (in anticipation of the Lebel keyboards) we had marked the CR key DOIT and thus the metaphor of "tell the computer or turtle to DO IT." Unfortunately the key was no longer so marked. But Est developed an interesting way out as a result. This little anecdote will be discussed later.

I had not made a firm plan because I wanted to see what she remembered, how she had changed, what the atmosphere was like. I didn't want to burden her with last year's experience. I had wanted to start off fresh and she too wanted that so I cleaned out her workspace. Intellectually we'd build on what she knew but we wouldn't examine last year's work. (Have you ever tried to understand a program you wrote six months ago!) I asked her to make the turtle draw a square or a box. She preferred to think of it as a box. (Last year she had written a procedure called BOX.) I told her in review that RT 90 headed the turtle from NORTH to EAST.

She made a square. Using TEACH (another result of work with Lin) she defined FOX, her box. I helped her by writing down what she did and reading it out to her. But now I wanted to make her independent. I posed the following problem. Make another FOX under the first like this:

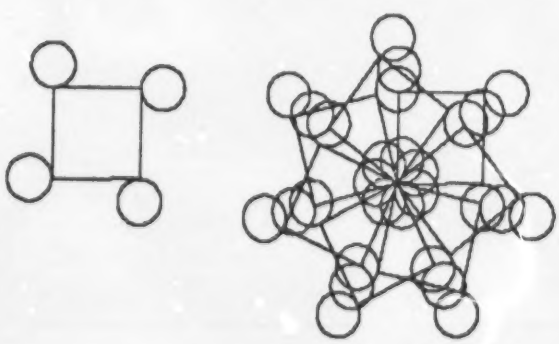


The turtle drew FOX and its stopping state was 90 degrees left of its starting state. This made the problem harder, more distracting. Est kept producing



The turtle's actions upside down!

or this



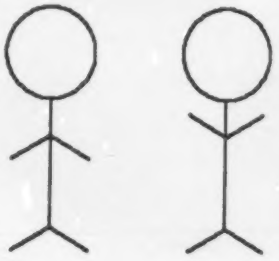
CS

FLOWER

but this was hard. I sat down and talked with her about the turtle's nose when it started and when it

stopped. I said "Maybe it would be easier if the turtle ended the same way as it started." So we changed FOX. She did find it easier.

Our next project was a man, a stick figure man. I drew it and said, "What's that?" "A man" she said.



We debugged it together facing the difficulties of this being the same as this , but upside down. I picked this kind of figure rather than one with different arms and legs because it is easier and harder. There are fewer parts making it easier, but the idea of representing arms and legs by the same procedure is a bit jarring the first time. It is, of course, part of exploiting the subprocedure game. Another new idea she encountered was having to relocate the turtle's starting state to accommodate the man's head. We had to back the turtle up 90 units before running the man procedure.

We taught the computer how to draw the LEGS/ARMS. First she taught the computer to EH which caused the turtle to draw this .

```
TO EH
10 RT 60    She knew she could choose another angle
20 FD 100
30 BK 100
40 LT 60    we emphasized the 2 part process
50 LT 60
60 FD 100
70 BK 100
80 RT 60
END
```

Now Est forgot for a moment that our plan had been to turn EH upside down. When she ran EH she complained it wasn't making legs. This is interesting because it often happens with older kids as well. The idea of rotating objects to make them be different is contrasted here with rotating objects to understand they don't change. But here we look at the object differently. This shape can only be arms, not legs, but rotated like this , it can be arms and legs.

She taught D.

```
TO D
10 RT 180   last year she would have said RT 90 RT
              90
20 EH
30 RT 180
END
```

She then put the pieces together and added a neck. This year she chose numbers like 150 and 40. Last year she would have picked 43, 49, etc. or 90.

When it was time to make a head there was very little screen space left. I saw it coming and began suggesting teaching the body parts to the computer. When she ran into the difficulty we were already making plans to deal with it. She taught UH and then before running it she backed the turtle 90 units. (This time she used 90. Was it because BK was not as familiar as FD?) When we made the head there were rotation decisions and then size decisions. She had forgotten the effect of RCIRCLE/LCIRCLE's input, it was the radius not the diameter, but one buggy drawing was a sufficient reminder. Here were her procedures, UH and RUTH. By the way, using D for both arms and legs worked out well and surprised me.

```
TO UH
10 D
20 FD 150
30 D
40 FD 40
END
```

```
TO RUTH
10 BACK 90
20 UH
30 LEFT 90
40 RCIRCLE 50
50 RIGHT 90
60 BACK 100   We took 90 away from 150 and added
                40.
END
```

The way we worked followed last year's pattern:

1. Draw something on paper.

2. Draw "it" on the screen using direct commands, including subprocedures already taught. The quoted it ("it") means that we are opportunistic. If something better turns up as we draw we might change our goal.

3. Now we teach the computer to do what we just did. (This is the step on which I shall concentrate in the next pages.) So the model for the learner is:

```
10  Do something
20  Teach the computer to do it
```

In more detail we could add:

5 Plan it first
15 Think about how you do it
25 Think about why it didn't quite work . . . debug

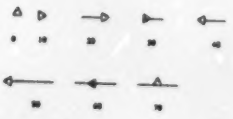
Next I asked Est to make another man without

Marie

destroying RUTH. We discussed how it differed from RUTH. This one was to be MARIE. Est really wanted to make MARIE and worked hard at it. What she could and what she could not do by herself revealed some interesting patterns I have often seen and talked about but which have not been discussed explicitly. So let's look in detail at her progress.

Remember RUTH used UH to make the body. UH ran D to make the arms and the legs. To make MARIE we want to replace UH by a new procedure (Est eventually called it S), but first she needed to replace D. She called her new procedure K.

```
TO K
10 RT 90
20 FD 100
30 BK 100
40 RT 180
50 FD 100
60 BK 100
70 RT 90
END
```



Est does not do this directly. Perhaps doing so is too "formal" for her age. Perhaps she was following a pattern I had set up last year. Whatever the reason her way was to "be MARIE herself", i.e., she would give the instructions as direct commands which would later be taught using TEACH. This is how she did everything. But there is more than one way to do this. So back to details.

I left Est entirely on her own. She worked for some X minutes and eventually produced the result she wanted on the screen. This obviously shows a mastery of FD, RT etc. as well as an ability to organize her work. But now comes a difficulty often seen in children this age. She has on the paper in front of her all the commands for MARIE. She knows how to use TEACH and certainly could have typed it all in (this she had done before). But her immediate goal was different. She set herself the sub-goal of "teaching the legs", i.e., of making a subprocedure K, which she would later incorporate into MARIE. But she blocks here. She seems to find it hard to isolate just the instructions she needs for this. Why? Is this a quirk of my teaching or something deep? Seymour says it looks like a "figure ground problem", "structure dependent perception", "reversibility" and like what J. Bamberger sees in children's descriptions of clapping. I don't know, but it feels like a real problem.

I watched from a distance and eventually decided to intervene following a principle of allowing children enough success soon enough to make the fight worth while. It needed hardly any intervention. In cases like this it usually doesn't need much. Often it is sufficient to say: "Ok, let's do it together." But then all I do is read to her what she sees on her paper. Another technique that gets the same result is to write, or have the child write, on a piece of paper just what she has typed to the computer. Why do these subtle things help? Because it is a trivial problem? Maybe. But perhaps also because it is a deep problem related to what psychologists might call attention and what we might call the control process of sub-procedure management. Anyway, it needed very little intervention and she was off on the track and soon Marie worked.

Research issues: understand this phenomenon, get better at observing just what intervention works and why, track the progress of a child over longer periods.

SOME GENERAL OBSERVATIONS

1. Compared with last year Est could work much more independently. (More than half a year is a big piece of her life!)

2. Her work with RCIRCLE and LCIRCLE would have been easier if the inputs were diameter (which "exists") rather than radius (which is about a non-existent point called center). Although later she made a design which was understandable because the input was the radius.

3. She had trouble remembering to ↵. This she cured by playing this game with the computer: after typing an instruction she would say, firmly and dramatically "DO IT" while hitting the CR key. She knew what "game she was playing". There was no trace of my manipulating her. On the contrary she manipulated herself. We'll see another good example in day 2 of how she is able to set up a deliberate strategy of programming around her own perceived bugs.

I set up the model for DO IT and feel that the way I did it (the rhythm, the degree of "reality" and also playfulness, etc.) made a very big difference as to whether this kind of thing works. On Day 2 she invented similar techniques of her own. So perhaps my suggestion took only because it was a kind of thing she does spontaneously. Big research issue!!

Day 2—Preamble:

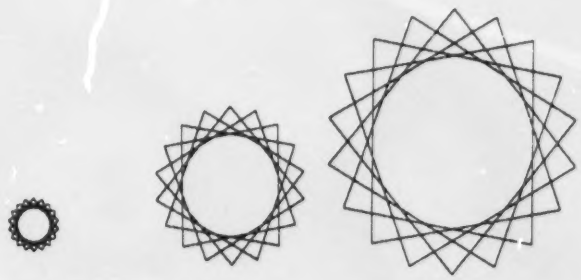
Again I had no detailed plan except the general idea of making an animation in which RUTH and MARIE alternate to give a jumping effect. I had written a new aid to help in snapping pictures called TS whose effect is to save SNAPs. But when I used it with Est I hadn't tried it out and it had a bug! I really got flustered by that. Lesson: don't use undebugged stuff, but if you do don't get flustered.

To warm up I showed Est POLY. She played with inputs. I showed her POLY 50 90. Then I asked her to change the shape. She tried POLY 50 80. She didn't want to call it a star (a 9 pointed star), then she tried POLY 50 40, POLY 50 60. Then she tried POLY 20 30, and POLY 20 20. She remarked that the last two were different sized circles. Finally she tried POLY 20 100 followed by POLY 50 100. She had to struggle with the idea that the 2 figures were the same shape. The first one was very tiny. So she tried POLY 100 100. That she thought could be the same as POLY 50 100, but still the size of the figures did bring into question whether the shape was the same.

My intention on the day before was to make an animation using RUTH and MARIE. We continued to work on this scheme after I fixed a TS bug. When I discussed what we had to do:

```
DISPLAY :RUTH
WIPECLEAN
DISPLAY :MARIE
WIPECLEAN
```

and do these steps over again, I then added we want



the computer to wait and suggested that it WAIT 5. The following conversation ensued.

E: Does that mean 5 seconds
C: No
WAIT 60 is a second
E: But if I say 1 that's a second
C: Yes but computers count faster.

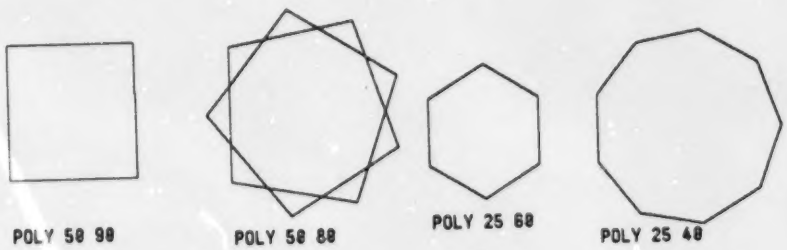
Then Seymour intervened and played a RACE with her. He wrote RACE. It took an input, a starting number and then counted up to 21 by one's. So

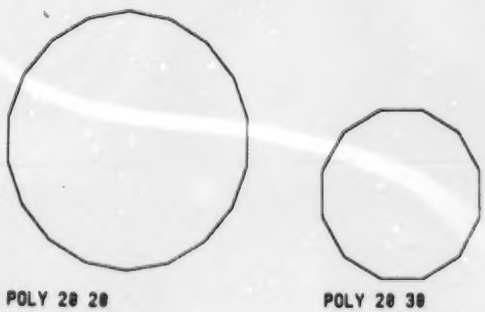
RACE →1 2 3 4 5 6 7 8 . . . 21

He asked Est to count against the computer. The computer won.

The racing and counting seemed to give another dimension and added more reality to some aspects of the computer:

> . . . its sequential behavior (After all up to now the results of her programs have been static. So even if





the drawing is sequential, the static may be more real.)
. . . its sense of time
. . . its quickness (even though this isn't in the nano-second range.)

She finished teaching P to the computer. She and I resumed our discussion about recursion. P was to be recursive. We had played the people procedure game (To POW RAISE-ARM LOWER-ARM SAY-POW) last year but she didn't remember. I asked her to be the POW procedure and we worked through it again. Then she made P behave in the same way and ran it. The desired effect was achieved.

I asked her to use LCIRCLE and RCIRCLE to make

she quickly made
out of LCIRCLE 90 and
LCIRCLE 60

Again an interesting phenomenon (the "start up bug"): she seemed to block until I said "What about moving the turtle?" A trivial piece of advice. Perhaps it really means "stop being complicated, do something simple."

She asked how much to move it. I answered, "Well it walks 90 units to the middle of the big circle and 60 units to the middle of the small so move it 90 take away 60. She did and completed the picture. We then took a break for lunch.

By the way I had tried to accept her first version but she would not give up on the original picture.

After lunch I asked her to make

This time using LC or RC (which took diameter as their input).

Then I went away. I suspected she had ritualized her experience with the head of RUTH and MARIE.
I wanted to see if she could undo it.
She worked very hard.

She got

I finally modified the model to

She said no she only wanted 1 leaf. (Esthetics).
She did it! She called it DF for dumb flower (again emphatic and dramatic).

In all this I see another interesting phenomenon. Call it making cliches. Are they good or bad? Perhaps necessary. Anyway that's how it seems to go. (Seymour says it now has the blessing of "frame theory" and something cognitive psychologists call "stereotyping". Again I don't know but I'm glad to know that theoretical people are paying attention to the things that seem important. Also, what does Piaget mean by schema?)

Here is a series of events.
In making the men Est constructed

The obvious first pass at doing this is

```
FD 50
RCIRCLE 50
```

but this gives

The debugged version is FD 50

LT 90
RCIRCLE 50

Est worked awhile on this and eventually knew how to make figures like

Now the flower model called for

which Est had previously found easier. But now she has trouble. She has "formed a cliche" or "overgeneralized" or whatever. You might say "well she doesn't understand anything. She is echoing mechanically." But it's not so simple. Look at what happened when I suggested putting in a leaf to form:

She didn't make

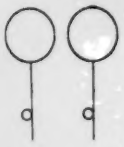
as she would if "LT 90 RCIRCLE" had been completely ritualized. So it's more subtle. Actually Est had developed another cliche. Instead of saying LT 90, she would say RT 90, RT 90, RT 90. In this problem there was payoff. Then she would always turn the turtle right.

My next suggestion was to make a row of flowers. She did

DF
DF

but the second DF drew the same flower again. Astonishment! Bug! Again a very "trivial" piece of advice got her going. I pointed to where the next flower could be. No words were necessary (what a lesson for talkative teachers!) . . . she knows how to drive the turtle and she quickly drew a row of flowers.

DF
RT 90
FD 50
RT 90
RT 90
RT 90
DF
RT 90
etc.



"Fantastic" I said, "and what about one to the left." Serious thinking. It has to go BK 150 she said, "because there are 1 2 3 of them."

Again the research problem: What do these "little" aids mean? What is the learner's problem. This learner sometimes handled this amazingly. Her flower drawer is called DF. Like many children her age she sometimes reverses letters and especially since FD is a LOGO word. So several times her intended DF got the reply:

FORWARD NEEDS MORE INPUTS

So she wrote a big DF on a piece of paper. Put a circle around it and looked at it ritualistically every time she wanted to draw a flower! (Best model this year of debugging.)

I emphasize: the particular trick for DF was entirely her own idea. If I helped it was by conveying (rather than telling) an attitude to debugging and towards using paper and pencil as a material aid. I had often taken up the pencil in times of difficulty.

Finally another "cliche" which I already mentioned, Est never used LEFT spontaneously. She knew what it

did and would oblige if asked to use it. But on her own she would say

```
RT 90
RT 90
RT 90
```

rather than

```
LT 90
```

There seemed to be no reason to complain or "correct" this perfectly adequate representation! It might be interesting to watch its development. But probably not. One day she will use LT 90 and no one will ever know what happened. Except her, perhaps.

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